UNCLASSIFIED

Defense Technical Information Center Compilation Part Notice

ADP015025

TITLE: Simple Method to Control the Nonlinear Dynamics of a Ball of Fire in a DP Machine Plasma

DISTRIBUTION: Approved for public release, distribution unlimited

This paper is part of the following report:

TITLE: International Conference on Phenomena in Ionized Gases [26th] Held in Greifswald, Germany on 15-20 July 2003. Proceedings, Volume 4

To order the complete compilation report, use: ADA421147

The component part is provided here to allow users access to individually authored sections of proceedings, annals, symposia, etc. However, the component should be considered within the context of the overall compilation report and not as a stand-alone technical report.

The following component part numbers comprise the compilation report:
ADP014936 thru ADP015049

UNCLASSIFIED

Simple Method to Control the Nonlinear Dynamics of a Ball of Fire in a DP Machine Plasma

Dan-Gheorghe DIMITRIU, Erzilia LOZNEANU, Codrina IONIŢĂ*, Mihaela MIHAI-PLUGARU, George AMARANDEI, Cezar GĂMAN, Mircea SANDULOVICIU, Roman SCHRITTWIESER*

Faculty of Physics, "Al. I. Cuza" University of Iasi, Bd. Carol I No. 11, RO-6600 Iaşi, Romania
*Institute for Ion Physics, "Leopold-Franzens" University of Innsbruck, Technikerstr. 25, A-6020 Innsbruck, Austria

We present a simple experimental method to obtain harmonic oscillations of the current in the presence of a ball of fire, in a DP machine plasma. By insertion of a coil in the external electrical circuit we can suppress all the higher harmonics, transforming the nonlinear oscillations into sinusoidal ones.

1. Introduction

By applying a positive potential to an electrode immersed in a plasma, in front of it a complex space charge configuration (CSCC) in form of a spherical double layer (DL) can appear [1,2], which is also sometimes called ball of fire. If the value of the potential on the electrode is large enough, the CSCC shows spatio-temporal dynamics related with the formation and disruption of the DL [3,4]. The plasma system performs strongly nonlinear oscillations, characterised by the presence of many higher harmonics in their spectrum. But, for many applications, purely harmonic oscillations are required, so we need to suppress the higher harmonics. This is possible by inserting an inductance into the external electronic circuit, in series with the electrode and the power supply. The oscillation frequency depends on the inductance according to Thomson's formula.

2. Experimental results and discussion

The experiments were performed in the DP machine of the University of Innsbruck, which has been described elsewhere [5]. The plasma created in the source chamber was pulled away from thermal equilibrium by gradually increasing the voltage applied to a tantalum disk electrode with 2 cm diameter. The argon pressure was $p = 5\times10^{-3}$ mbar and the plasma density $n = 10^{10}$ cm^{-3}. By applying a voltage $V_E = 75$ V to the electrode we obtain high-amplitude current oscillations, represented in Fig. 1a. Fig. 1c shows the spectrum of these oscillations. We observe the existence of many higher harmonics, and the oscillations are strongly nonlinear. To characterise the oscillations, we present the autocorrelation function (Fig. 1e) and the reconstructed phase space (Fig. 1g), obtained by using the method of delays, proposed by Packard *et al.* [6], Ruelle [7] and Takens [8]. To control these current oscillations we have inserted a coil with the inductance L into the external electrical circuit, in series with the electrode and the power supply. The proper choice of L can lead to the transformation of nonlinear oscillations into harmonic ones. Figs. 1b, 1d, 1f and 1h show the current oscillations, the FFT, the autocorrelation function and the reconstructed space, respectively, for the case when the coil is inserted. We observe the disappearance of all higher harmonics from the spectrum, with the oscillations assuming a sinusoidal shape. The reconstructed space has a perfect circular shape, which is characteristic for harmonic oscillations. The square of the oscillation frequency depends on the inverse of the inductance, according to Thomson's formula.

The oscillatory state before connecting the coil corresponds to the transition of the DL into a propagating state, during which new DLs are successively generated and detaching from the electrode [3,4]. The frequency of these oscillations is determined both by the values of external circuit elements and by the characteristics of the plasma (including the DL). The existence of many higher harmonics in the spectrum (Fig. 1c) is an indication for the strong nonlinearity of the oscillations. These higher harmonics can be very advantageous in some applications, as e.g. high frequency generators. But in most of the applications it is preferable to generate harmonic (sinusoidal) oscillations. According to the Thomson formula, we can obtain harmonic oscillations by modifying the capacitance or the inductance either of the plasma, or of the external electrical circuit elements (capacitors and coils). Our choice was to insert an inductance into the external electrical circuit and to find a suitable value of the inductance in such a way that the obtained current oscillations will be harmonic (Fig. 1b). In this case we obtain a resonance between the power source of oscillations (the dc power supply) and the oscillatory circuit (plasma together with the external electrical circuit elements).

3. Conclusions

We propose a simple method to control the nonlinear dynamics of a ball of fire in DP machine plasma. The method eliminates all higher harmonics of a strongly nonlinear oscillation obtaining a purely sinusoidal one.

References

[1] R. A. Bosch, R. L. Merlino, *Contrib. Plasma Phys.* **26** (1986) 1;

[2] B. Song, N. D'Angelo, R. L. Merlino, *J. Phys. D: Appl. Phys.* **24** (1991) 1789;

[3] M. Sanduloviciu, C. Borcia, G. Leu: *Phys. Lett. A* **208** (1995) 136;

[4] E. Lozneanu *et al.*: *J. Plasma Fus. Res. SERIES* **2** (1999), 389;

[5] R. Schrittwieser *et al.*, *Physica Scripta* **T84** (2000), 122;

[6] N. H. Packard *et al.*: *Phys. Rev. Lett.* **45** (1980) 712;

[7] D. Ruelle: in *Chaotic Evolution and Strange Attractors*, Cambridge University Press, Cambridge 1989;

[8] F. Takens: in *Dynamical Systems and Turbulence, Lecture Notes in Mathematics vol. 898* (Eds. D. A. Rand, L. S. Young). Springer-Verlag, Berlin 1981.

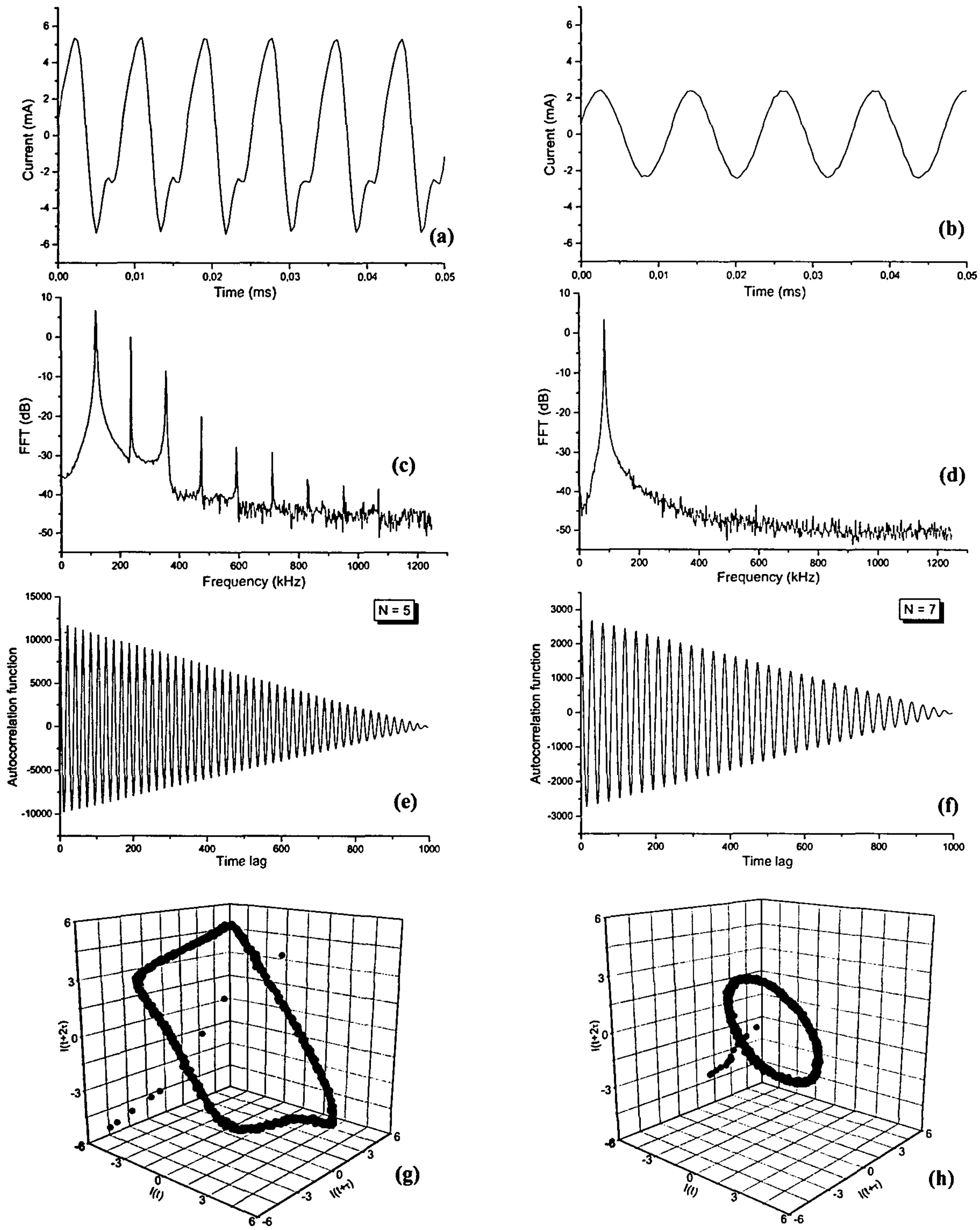

Fig. 1: Time series, FFT, autocorrelation function and 3D Poincaré map through the reconstructed phase space of the current oscillations, respectively, before (left column) and after (right column) the insertion of the coil.